SHARK NURSERY GROUNDS AND ESSENTIAL FISH HABITAT STUDIES

GULFSPAN GULF OF MEXICO-FY05
Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey

REPORT TO NOAA FISHERIES, HIGHLY MIGRATORY SPECIES OFFICE

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BACKGROUND

Identification and conservation of essential fish habitat are important components of providing adequate management and conservation for shark populations. This is of particular importance when attempting to understand the dynamics of sharks in coastal nursery areas. This report describes results from the Cooperative Gulf of Mexico Shark Pupping and Nursery Project (GULFSPAN) for 2005.

METHODS

Surveys were modeled after those developed by Carlson and Brusher (1999) to provide a direct comparison of abundance among areas. A 186-m long gill net consisting of six different mesh size panels was used for sampling in all areas. Stretched mesh sizes ranged from 7.6 cm (3.0") to 14.0 cm (5.5") in steps of 1.3 cm (0.5"). The sampling gear was randomly set within each area based on depth strata and GPS location. Nets were fished in northwest Florida, Mississippi/Alabama, and Louisiana from April to October. Captured sharks were measured (precaudal, fork, total, and stretched total length), sexed, and life history stage assessed and recorded (young-of-the-year, juvenile, or adult). Sharks that were in poor condition were sacrificed for life history studies and those in good condition were tagged and released. Rays captured were measured in disc width and sexed. Because of the limited life history information for most ray species, a life history category could not always be assigned in the field. For each set of the gear, mid-water temperature (^{o}C), salinity (ppt) and dissolved oxygen (mg l^{-1}) were recorded from a YSI-85 environmental meter, depth (m) was recorded from the vessel's depth finder, water clarity (depth of the photic zone in cm) was measured by secchi disc, and qualitative habitat type was (e.g., mud, sand, oyster) determined by personal observation or previously documented literature.

RESULTS

1. Northeastern Gulf of Mexico

Abundance trends

Sampling sites were located in four major areas along the northeastern portion of the Gulf of Mexico: St. Andrews Bay, Crooked Island Sound (Figure 1), St. Joseph Bay, and Apalachicola Bay, FL (Figure 2). Sampling was conducted from April to October. A total of 149 sets were made capturing 9 species of sharks and 3 species of rays. The majority of individuals encountered were immature.

The Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, a member of the small coastal management group, was the most abundant shark captured (29-104 cm TL, mean = 71.9 cm TL; Table 1a). The bonnethead shark, *Sphyrna tiburo*, was the second most abundant shark species encountered (43-111 cm TL, mean = 60.9 cm TL; Table 1d). The blacktip shark, *Carcharhinus limbatus*, was the third most abundant species captured overall and the most abundant shark captured from the large coastal management group (55-137 cm TL, mean = 91.6 cm TL; Table 1c). The remaining species captured in decreasing abundance were the finetooth shark, *C. isodon* (60-142 cm TL, mean = 104.1 cm TL; Table 1f), scalloped hammerhead shark, *S. lewini* (45-93 cm TL, mean = 77.5 cm TL; Table 1h), spinner shark, *C. brevipinna* (66-115 cm TL, mean = 86.3 cm TL; Table 1i), blacknose shark, *C. acronotus* (40-125 cm TL, mean = 73.1 cm TL; Table 1b), sandbar shark, *C. plumbeus* (107-132 cm TL, mean = 119.5; Table 1g), and bull shark, *C. leucas* (128 cm TL; Table 1e).

The cownose ray, *Rhinoptera bonasus*, was the most abundant ray captured (34-95 cm DW, mean = 68.9 cm DW; Table 2b). Other ray species captured in decreasing abundance were the bluntnose stingray, *Dasyatis sayi* (24-42 cm DW, mean = 33.0 cm DW; Table 2a), and devil ray, *Mobula hypostoma* (73-73.5 cm DW, mean = 73.3 cm DW; Table 2c).

Species Essential Fish Habitat Profiles

Essential fish habitat requirements (EFH; e.g., temperature, salinity, etc.) for elasmobranchs collected in the northeastern Gulf of Mexico were relatively similar (Tables 3-14).

As the majority of life stages of sharks collected were young-of-the-year and juveniles, areas in the panhandle of Florida remain important nurseries for both large and small coastal shark species. In general, young-of-the-year sharks were more often collected in waters with higher temperature, lower salinity, shallower water, and more turbid conditions compared to juveniles and adults (Tables 3-11). These small, young sharks may be selecting shallow water habitats that are warmer and have more of a freshwater influence as a haven from large, more active predators.

Except for the cownose ray, EFH requirements for ray species were sparse (Tables 12-14). Interestingly, ray species were found in a wider range of salinities than sharks (17.0 low, 36.0 high for rays; 23.5 low, 35.2 high for sharks). Cownose ray data suggests that adults (~68 cm DW) can tolerate a much wider range of environmental factors than smaller life stages (Table 13).

Predator-prey and trophic relationships

Atlantic sharpnose shark, *R. terraenovae*, diet was described from Crooked Island Sound, FL. Diet was assessed by life-stage and quantified using six indices: percent by number, percent by weight, frequency of occurrence, the index of relative importance (IRI), IRI expressed on a percent basis (%IRI), and %IRI based on prey category (%IRI_{PC}). Identifiable prey items were categorized into six major prey categories (PC) following Bethea et al. (2004): (1) Family Clupeidae, (2) other pelagic teleosts, (3) Family Sciaenidae, (4) other epibenthic teleosts, (5) crustaceans, (6) other invertebrates. Young-of-the-year sharks (n = 56) fed on a mix of teleosts (mostly clupeids, 44.6 %IRI_{PC}) and invertebrates (combined, 25.1 %IRI_{PC}), juveniles (n = 185) on sciaenids (40.7 %IRI_{PC}) and clupeids (37.8 %IRI_{PC}), and adults (n = 105) fed on sciaenids (71.4 %IRI_{PC}). Differences in diet by site and ontogeny were tested by comparing diet from Crooked Island Sound with published information from St. Vincent Island in Apalachicola Bay, an adjacent estuary. Stomach contents were also used to expand on published prey size-predator size information. Spearman correlation analysis, Pianka's overlap values, null-model simulations, and simple correspondence analysis showed that life stage diet differed within and between sites. Three of four size-selectivity tests showed negative size selection. Absolute prey size and the range in absolute prey size increased with increasing shark size. Atlantic sharpnose shark diet was dominated by prey that were <40 % of shark length; however, 75 % of prey items were 21-40 % of shark length while 25 % were <20 % of shark length. Variations in diet composition within and between the two sites are likely due to differences in shark size, overall habitat structure, and availability of potential prey species. Results of this study are currently in press (Bethea et al., In press).

Through collaboration with Mote Marine Laboratory, the diet and daily ration of the bonnethead shark, *S. tiburo*, was described from three areas in the eastern Gulf of Mexico: northwest Florida, Tampa Bay, and Florida Bay. In each area, diet was assessed by size classes (40-60, 61-80, and 81-100+ cm TL) and quantified as above. Diet was not assessed for sharks 40-60 cm TL in Tampa Bay due to small sample size. $\%IRI_{PC}$ was based on 10 prey categories: (1) *Halodule wrightii*, (2) *Thalassia testudinum*, (3) other plant material (including unidentified plant material), (4) cephalopods, (5) other molluscs (including unidentified molluscs), (6) decapod crabs, (7) lobsters, (8) decapod shrimps, (9) other crustaceans (including unidentified crustaceans), and (10) Osteichthyes. In the northwest Florida areas, a mix of decapod crustaceans other than lobster were found in stomachs of sharks 40-60 cm TL (n=78). Stomachs of sharks 61-80 cm TL (n=60) and 81-100+ cm TL (n=51) contained mostly crabs. The same trend was observed in Tampa Bay for the larger two size classes of sharks (n=103 and n=61, respectively). In Florida Bay, sharks 40-60 cm TL (n=27) fed on crustaceans and cephalopods, sharks 61-80 cm TL (n=90) took fewer crabs and shrimps and more lobsters and cephalopods, while the diet of sharks 81-100+ cm TL (n=38) was dominated by cephalopods, lobsters, and crabs. Sharks at all locations consumed large amount of plant material. Analysis showed diets from northwest Florida and Tampa Bay to be similar, consisting of mostly decapod crabs. Diets of sharks from Florida Bay were different, consisting of more cephalopods and lobsters. Sharks in all areas consumed prey that were very small fractions of their total length; 95.6 % of all prey measured were <13 % of shark length. A bioenergetic model was constructed to estimate daily ration using diet data from this study and species-specific inputs from other studies. Daily ration was different among areas and size classes. Daily ration was highest for sharks 40-60 cm TL and lowest for sharks 81-100+ cm TL. Results of this study are currently in preparation for submission to the journal of Marine Biology (Bethea et al., In prep). Future research on bonnethead sharks will be in conjunction with colleagues from the University of Hawaii, using heavy isotope analysis on muscle tissue to determine trophic level.

Skates are an important component of benthic marine ecosystems. Fishery management stresses the need for an ecosystem approach, but skates have often been ignored. To evaluate trophic role, the diet and feeding habits of the roundel skate, *Raja texana*, have been examined from offshore waters in the northern Gulf of Mexico. Diet was assessed by life-stage and quantified as above. $\%IRI_{PC}$ was based on 4 prey categories: (1) decapod crab, (2) decapod shrimp, (3) other crustaceans (including unidentified crustaceans), and (4) Osteichthyes. Preliminary analysis of stomachs from 31 juveniles (25 non-empty; mean DW=23.5 cm) and 46 mature individuals (39 non-empty; mean DW=32.2 cm) indicate shrimp make up 95 $\%IRI_{PC}$ of juvenile skate diet with Family Solenoceridae as the most important (22.1 %IRI). Osteichthyes (*Micropogonias undulatus* and *Ophidium* sp.) were also found in the diet of juvenile skates although in much smaller amounts (0.9 %IRI and 2.9 %IRI, respectively; 3.2 $\%IRI_{PC}$ overall). Mature skate diet was also predominantly shrimp (58.6 $\%IRI_{PC}$). Crab and other crustaceans (e.g., *Squilla* sp.) were also found in the diet (2.3 and 17.4 $\%IRI_{PC}$, respectively). Osteichthyes (all unidentifiable) made up 21 $\%IRI_{PC}$ of mature skate diets. Preliminary analysis does not indicate ontogenetic diet shifts; however, mature individuals consistently have larger and more than one prey item or type in their stomachs. Results of this study will be presented at the skate symposium at the 2006 Joint Meeting of the American Society of Ichthyologists and Herpetologists and the American Elasmobranch Society (Bethea and Hale, In prep). Proceedings from the symposium will be published in a peer-reviewed journal yet to be determined.

Telemetry

In March 2005, an array of stationary underwater acoustic receivers (VEMCO Ltd. VR1) was placed in Crooked Island Sound, FL, for a second season of data collection on age-1 Atlantic sharpnose sharks, *R. terraenovae*. The array consists of 12 acoustic receivers and is used to continuously monitor movements of individuals from May through October in an area of ~30 km^2. This year, HOBO data loggers (Onset Computer Corp. UA-002-64) were attached to four VR receivers throughout the bay. HOBO data loggers monitor temperature and light intensity every 30 minutes. The data collected by this system are currently being used in a broad range of studies to help better understand the role of elasmobranchs within the estuary, study changes in habitat use through time, examine intra- and interspecific relationships (e.g. predator-prey, competition, and group dynamics), and determine how anthropogenic (e.g., water use patterns and habitat alteration) and natural disturbances (e.g., hurricanes and red tide) impact resource use. This study will continue for a third and final year in 2006.

Beginning in August 2005, 5 bull sharks, *Carcharhinus leucas* (mean size=150 cm FL), were tagged with archival satellite tags to acquire better data on habitat use and short- and long-term movement patterns while in summer coastal areas. Of the 5 sharks that were tagged, 2 (#4 and #6) reported back after 20 and 58 days respectively. Preliminary analysis of the data indicates shark ranged very little over the time tagged and randomly moved throughout the coastal zone (Figure 3). This study will also continue in 2006.

2. Mississippi/Alabama

C*atch rates*

A total of 24 sets at nine sampling stations were performed from May to October 2005 in Mississippi coastal waters (Figure 4). A total of 111 sharks were collected, representing five species. Of these, 75% of were immature. The Atlantic sharpnose, *R. terraenovae* (39.2-103.0 cm TL), was the most abundant species caught followed by the blacktip shark, *C. limbatus* (57.0-148.0 cm, TL), finetooth shark, *C. isodon* (54.8-83.6 cm TL), bull shark, *C. leucas* (85.0-127.0 cm TL), and bonnethead shark, *S. tiburo* (73.8-93.2 cm TL). A total of three rays were collected, representing two species, the Atlantic stingray, *Dasyatis americana* (43.0 cm DW), and the cownose ray, *R. bonasus* (77.5-87.5 cm DW).

For all combined life stages, Atlantic sharpnose and bonnethead sharks were most abundant off Horn Island. Blacktip, finetooth, Atlantic sharpnose, and bonnethead sharks were most frequently caught off Round Island. Blacktip and bull sharks were collected in waters north of Cat Island. The bull shark was the only species collected from Davis Bayou. Both cownose rays were collected at Horn Island and the Atlantic stingray was collected at Cat Island.

Round Island was the most productive location (8.8 sharks net hr^{-1}), followed by Horn Island (3.3 ± 2.2 sharks net hr^{-1}), Cat Island (2.4 ± 1.4 sharks net hr^{-1}), and Davis Bayou (2.3 ± 1.5 sharks net hr^{-1}; Table 2). The most productive months were May (7.5 sharks net hr^{-1}), June (8.8 sharks net hr^{-1}), and July (2.9 ± 0.9 sharks net hr^{-1}) followed by a noticeable decline in August (1.09 sharks net hr^{-1}), September (1.9 ± 0.6 sharks net hr^{-1}) and October (0.4 ± 0.4 sharks net hr^{-1}).

Species Essential Fish Habitat Profiles

Information on essential fish habitat requirements (e.g., temperature, salinity, etc.) for the five shark species were relatively similar (Tables 15-20); however, there were a few interesting observations. The majority of sharks collected in this study were immature, suggesting that Mississippi Sound is an important nursery area for several shark species. Young-of-the-year (all species) appeared to prefer higher water temperature, lower salinity, shallower depth, and more turbid waters compared to juvenile and adult life stages (Tables 15-19). These small sharks may be selecting shallow water habitats that are warmer and typically have more of a freshwater influence, which lowers the salinity and turbidity.

The majority of the sharks were collected in relatively higher salinity waters (21.0-27.4 ppt; Tables 15-19); however, only young-of-the-year and juvenile bull sharks were collected in >14 ppt, which was expected since young bull sharks appear to prefer lower salinity environments.

The Atlantic stingray and cownose ray are very common within the waters of Mississippi Sound. All rays were collected at Horn and Cat Islands in waters with relatively high salinity (22.0-26.7 ppt), warm water temperature (26.8-31.4˚C), and similar bottom type (sand/silt; Table 20).

3. Louisiana

Southeastern Louisiana was hit by Hurricane Katrina causing severe damage to the coastal zone east of the Mississippi River. Research could not be completed in the sampling areas following the storm as gasoline and access to marinas were unavailable, roads were blocked, and great amounts of debris were in the water. In addition, Louisiana State University was closed for long periods due to storm damage. This area will begin sampling again in 2006.

STOCK ASSESSMENT

Fishery-independent estimates of relative abundance are presently limited but can be the best estimator of the status of shark stocks. Data collected as part of the GULFSPAN project has been and will be incorporated into stock assessment models (Cortés, 2002; Cortés et al., 2002). Because surveys in this project are designed to target juvenile sharks, estimates of juvenile abundance provide promising alternatives to traditional hind-casting models and improve the ability to assess current and future shark stock size and strength. In addition, catch rate information for juvenile sharks is critical in developing age-structured stock assessment models. In October 2005, data collected from Mississippi/Alabama and northwest Florida were standardized into trends of abundance for large coastal species.

The Mississippi/Alabama shark survey began in 1998 as a three year study funded by the Marine Fisheries Initiative Program (MARFIN). In 2001, the survey was partially continued (unfunded) in an effort to preserve some of the long-term monitoring of shark numbers. The following year no effort was put towards continuing the survey. In 2003, the GULFSPAN Project was established and funds were provided to continue monitoring the local shark species. Catch rates for blacktip sharks were consistent from 1998 to 2005, except for two relatively high values during 2000 and 2005 (Hoffmayer and Parsons, 2005). This phenomenon was also observed with Atlantic sharpnose and finetooth sharks. Both 2000 and 2005 were very similar in regards to water temperature and the amount of rainfall; both years were considered drought years. The water temperature was also elevated earlier in the year. It is thought that the elevated water temperature and salinity helped to concentrate the sharks into the sampling area and made them more available for capture. Excluding these two years, catch rates appear to be relatively constant over the seven year time series for Mississippi coastal waters.

In northwest Florida, catch rate series from 1996-2004 were developed for blacktip and sandbar sharks. Two additional catch rate series are also developed by age for the blacktip shark; young-of-the year (age 0+) and juvenile (age 1-5) (Carlson and Bethea, 2005). Catch rates were relatively stable over the time period but there were inter-annual fluctuations in abundance. Whether these fluctuations were do to environmental conditions or year to year variation in recruitment has not been determined.

CONCLUSIONS

New information on habitat preferences and essential fish habitat is emerging as this study concludes its third year. For the first time in several years, sampling in the northern Gulf of Mexico occurred on the gulf-side of St. George Island and just inside Sikes Cut in Apalachicola Bay, FL. While sets made in these areas were few, presence/absence data show that fewer elasmobranchs and potential prey species were caught inside the bay and on the gulf-side of St. George Island as opposed to the gulf-side of St. Vincent Island. This may be due to habitat structure and prey availability. Salinity inside Apalachicola Bay is low due to freshwater outflow from the Apalachicola River and bottom type is mostly shallow water over oyster beds and mud. The gulf-side of St. George Island has higher salinities and is characterized by sandy bottom. The gulf-side of St. Vincent Island is a mix of clay, sand, and mud over a limestone bottom (Livingston, 1984) and several potential prey species are collected there throughout the year. More sets will be made in these new areas in the coming year.

Evidence from habitat association tables still indicates that bull sharks inhabit the most diverse environmental conditions. They were captured in salinities ranging from 10.1 ppt (in Mississippi) to 30.1 ppt (in northwest Florida) and over a range of habitat types. Although bull sharks can be found over a variety of habitats, the areas of highest abundance are those adjacent to freshwater inflow. Juvenile sandbar sharks are still being caught in the northeast Gulf of Mexico, particularly on the gulf-side of St. Vincent Island, while Atlantic sharpnose, blacktip, bonnethead, and finetooth sharks as well as cownose rays are found throughout all areas.

Information critical to Essential Fish Habitat continues to develop regarding trophic relationships and feeding habitats in elasmobranchs. While preliminary, results show that roundel skates feed mostly on shrimp and crab species regardless of predator size. Similar to Atlantic sharpnose sharks, bonnethead sharks have very different diets depending on area. Bonnethead sharks in the north and eastern Gulf of Mexico feed heavily on decapod crabs while those in the southern gulf take more lobster and cephalopods. Variations in diet composition between nursery areas are likely due to differences in habitat structure and availability of potential prey species. These variations could affect growth. Understanding how sharks use nursery habitats and determining which habitat types have high “nursery values” requires quantitative examination of feeding ecology from different proposed nurseries (sensu Beck et al., 2001). Additionally, bonnethead sharks in all locations throughout the Gulf of Mexico have large amounts of plant material in their diet – something that has not been documented in any other species of shark. Whether or not plant material provides this species of shark with any nutritional value is still to be determined.

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Table 1. Summary of CPUE (number of sharks/net/hour) for sharks by life history stage and major area sampled in the northeast Gulf of Mexico. Means (standard deviations) are presented. Young-of-the-year includes neonate life stage. Specimens with an undetermined life stage are included in total CPUE calculation. Species are listed alphabetically by common name.

(a) Atlantic sharpnose shark, *Rhizoprionodon terraenovae*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	0.35 (1.10)	0.01 (0.08)	-	0.19 (0.88)
Juveniles	0.11 (0.42)	1.15 (3.10)	0.55 (1.48)	0.25 (0.50)	0.19 (0.63)
Adults	0.04 (0.19)	0.62 (1.21)	0.67 (1.99)	0.25 (0.50)	1.12 (1.88)
All	0.14 (0.45)	2.12 (4.20)	1.23 (2.79)	0.50 (1.00)	1.50 (2.11)

(b) Blacknose shark, *Carcharhinus acronotus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	0.06 (0.31)	0.18 (1.12)	-	-
Juveniles	-	-	-	-	-
Adults	-	-	0.12 (0.45)	-	-
All	-	0.06 (0.31)	0.29 (1.19)	-	-

(c) Blacktip shark, *Carcharhinus limbatus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	0.05 (0.32)	-	0.23 (0.82)
Juveniles	0.11 (0.31)	0.30 (0.69)	0.18 (0.45)	-	1.48 (2.39)
Adults	-	0.02 (0.41)	0.03 (0.11)	-	0.06 (0.22)
All	0.11 (0.31)	0.32 (0.78)	0.26 (0.63)	-	1.77 (2.59)

(d) Bonnethead shark, *Sphyrna tiburo*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	0.43 (1.73)	0.90 (2.04)	0.13 (0.52)	-	0.04 (0.20)
Juveniles	-	0.10 (0.41)	-	-	0.04 (0.14)
Adults	-	0.14 (0.40)	0.12 (0.39)	-	0.27 (0.62)
All	0.43 (1.73)	1.14 (2.25)	0.24 (0.63)	-	0.35 (0.69)

(e) Bull shark, *Carcharhinus leucas*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	-	-	-
Juveniles	-	-	-	-	0.02 (0.10)
Adults	-	-	-	-	-
All	-	-	-	-	0.02 (0.10)

(f) Finetooth shark, *Carcharhinus isodon*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	0.03 (0.15)	-	-	0.27 (0.83)
Juveniles	-	0.02 (0.14)	0.08 (0.35)	-	0.71 (1.42)
Adults	-	0.02 (0.14)	0.01 (0.08)	-	0.40 (1.12)
All	-	0.07 (0.24)	0.09 (0.36)	-	1.38 (2.68)

(g) Sandbar shark, *Carcharhinus plumbeus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	-	-	-
Juveniles	-	-	-	-	0.06 (0.22)
Adults	-	-	-	-	-
All	-	-	-	-	0.06 (0.22)

(h) Scalloped hammerhead shark, *Sphyrna lewini*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	0.08 (0.33)	-	-	0.19 (0.98)
Juveniles	-	0.02 (0.14)	0.64 (4.00)	-	-
Adults	-	-	-	-	-
All	-	0.10 (0.45)	0.64 (4.00)	-	0.19 (0.98)

(i) Spinner shark, *Carcharhinus brevipinna*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	0.18 (0.82)	-	0.08 (0.27)
Juveniles	0.04 (0.19)	0.04 (0.19)	0.05 (0.32)	-	0.44 (0.94)
Adults	-	-	-	-	-
All	0.04 (0.19)	0.04 (0.19)	0.23 (0.87)	-	0.52 (1.17)

Table 2. Summary of CPUE (number of rays/net/hour) for rays by major area sampled in the northeast Gulf of Mexico. Means (standard deviations) are presented. Young-of-the-year includes neonate life stage. Specimens with an undetermined life stage are included in total CPUE calculation. Species are listed alphabetically by common name.

(a) Bluntnose stingray, *Dasyatis sayi*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	-	-	-
Juveniles	-	-	-	-	-
Adults	-	0.02 (0.14)	-	0.25 (0.50)	-
All	-	0.02 (0.14)	0.03 (0.16)	0.25 (0.50)	-

(b) Cownose ray, *Rhinoptera bonasus*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	0.07 (0.38)	0.19 (1.01)	-	-	0.08 (0.39)
Juveniles	-	0.13 (0.53)	0.18 (0.51)	-	0.21 (0.71)
Adults	0.04 (0.19)	0.08 (0.33)	1.12 (3.32)	-	0.15 (0.61)
All	0.11 (0.42)	0.40 (1.54)	1.29 (3.61)	-	0.48 (1.34)

(c) Devil ray, *Mobula hypostoma*

Life stage	St. Andrew Bay	Crooked Island Sound	St. Joseph Bay	Apalachicola Bay (Inside)	Apalachicola Bay (Outside)
Young-of-the-year	-	-	-	-	-
Juveniles	0.07 (0.38)	-	-	-	-
Adults	-	-	-	-	-
All	0.07 (0.38)	-	-	-	-

Table 3. Summary of the habitat associations for the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.9 (21.0-31.3)	30.2 (26.7-34.0)	4.4 (2.4-7.0)	243.5 (100-325)	5.3 (3.8-7.9)	Mud/Sand
Juveniles	28.3 (18.4-31.5)	29.9 (23.5-33.0)	4.6 (1.5-8.1)	247.3 (100-500)	5.4 (3.9-7.9)	Sand/Mud/ Seagrass
Adults	27.8 (21.0-31.5)	30.3 (23.5-34.0)	4.8 (2.1-8.1)	270.8 (125-549)	5.4 (3.8-7.0)	Mud/Sand/ Seagrass

Table 4. Summary of the habitat associations for the blacknose shark, *Carcharhinus acronotus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.8 (29.8-31.3)	30.2 (28.1-32.4)	2.2 (1.5-3.0)	213 (150-250)	4.7 (4.6-4.8)	Sand/Mud
Juveniles	- -	- -	- -	- -	- -	-
Adults	25.9 (25.2-26.3)	30.5 (30.1-30.7)	5.0 (4.3-5.5)	502 (434-549)	6.2 (6.1-6.3)	Mud/Sand/ Seagrass

Table 5. Summary of the habitat associations for the blacktip shark, *Carcharhinus limbatus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.3 (28.8-31.2)	31.2 (28.8-32.5)	5.8 (4.3-7.0)	287.5 (275-300)	5.0 (4.1-5.9)	Mud
Juveniles	28.7 (23.8-32.9)	30.6 (24.2-34.0)	4.8 (2.9-8.1)	253.4 (100-549)	5.3 (2.3-8.3)	Mud/Sand/ Seagrass
Adults	30.1 (28.4-32.9)	32.3 (30.7-33.0)	5.4 (4.3-8.1)	262.5 (175-375)	5.2 (4.1-5.8)	Sand/Mud

Table 6. Summary of the habitat associations for the bonnethead shark, *Sphyrna tiburo*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	28.2 (21.1-32.3)	30.6 (22.9-34.0)	3.7 (1.9-5.0)	233.6 (110-440)	5.3 (3.5-7.9)	Sand/Mud/ Seagrass
Juveniles	30.2 (28.9-31.1)	29.5 (26.7-32.8)	5.0 (4.2-7.2)	221.3 (200-250)	4.6 (3.9-5.6)	Mud/Sand
Adults	26.5 (18.6-31.0)	31.3 (26.8-34.0)	4.1 (1.7-8.1)	247.1 (150-434)	5.6 (3.9-6.9)	Sand/Mud

Table 7. Summary of the habitat associations for the bull shark, *Carcharhinus leucas*, by life stage in the northeast Gulf of Mexico. Raw data are presented.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	- -	- -	- -	- -	- -	-
Juveniles	29.8 -	30.7 -	4.5 -	180 -	5.5 -	Mud
Adults	- -	- -	- -	- -	- -	-

Table 8. Summary of the habitat associations for the finetooth shark, *Carcharhinus isodon*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	25.8 (19.5-28.4)	33.9 (32.7-35.2)	3.8 (3.1-4.8)	125 (50-250)	5.5 (4.8-6.5)	Mud/Sand
Juveniles	28.2 (23.8-31.0)	31.1 (24.1-33.4)	4.1 (2.4-6.6)	168.9 (50-440)	5.5 (4.1-7.9)	Mud/Sand/ Seagrass
Adults	26.8 (21.2-31.0)	31.9 (29.0-33.4)	5.0 (3.4-6.6)	253.5 (150-549)	5.8 (4.1-7.5)	Sand/Mud

Table 9. Summary of the habitat associations for the sandbar shark, *Carcharhinus plumbeus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Values without ranges are raw data. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	23.7	30.7	5.7	155	6.9	Sand/Mud
	(21.2-26.2)	(29.0-23.2)	(3.4-8.1)	-	(7.5-6.4)	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 10. Summary of the habitat associations for the scalloped hammerhead shark, *Sphyrna lewini*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life. Means (ranges) are presented. Values without ranges are raw data. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	29.6	32.7	4.3	172	4.9	Sand/Mud
	(27.1-32.9)	(32.3-33.0)	(3.2-5.2)	(150-190)	(4.1-5.3)	
Juveniles	31.2	28.8	7.0	275	5.9	Mud
	-	-	-	-	-	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 11. Summary of the habitat associations for the spinner shark, *Carcharhinus brevipinna*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.3	29.8	5.1	260	4.5	Mud/Sand/
	(28.4-31.0)	(24.1-32.8)	(3.3-6.7)	(175-350)	(3.5-5.4)	Seagrass
Juveniles	28.4	31.7	5.1	186.7	4.9	Sand/Mud
	(19.5-32.9)	(26.0-34.7)	(3.1-7.2)	(50-350)	(3.6-6.5)	Seagrass
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 12. Summary of the habitat associations for the bluntnose stingray, *Dasyatis sayi*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Values without ranges are raw data. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	-	-	-	-	-	-
	-	-	-	-	-	
Adults	27.9	24.4	0.9	165	5.8	Sand/Mud/
	(24.7-31.1)	(19.7-29.0)	-	(120-210)	(5.6-5.9)	Oyster

Table 13. Summary of the habitat associations for the cownose ray, *Rhinoptera bonasus*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Means (ranges) are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	25.2	28.2	3.8	209	6.4	Sand/
	(21.0-30.5)	(18.3-32.0)	(2.9-4.9)	(120-305)	(5.4-7.9)	Seagrass/Mud
Juveniles	26.5	30.9	3.6	197.6	6.1	Sand/Mud/
	(21.2-31.3)	(28.1-34.0)	(1.5-6.6)	(100-350)	(4.3-7.9)	Seagrass
Adults	25.7	29.2	4.5	294.1	6.1	Mud/Sand/
	(19.3-31.5)	(17.0-36.0)	(1.5-9.1)	(110-549)	(4.1-7.9)	Seagrass

Table 14. Summary of the habitat associations for the devil ray, *Mobula hypostoma*, by life stage in the northeast Gulf of Mexico. Young-of-the-year includes neonate life stage. Raw data are presented. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	-	-	-	-	-	-
	-	-	-	-	-	
Juveniles	31.2	22.9	2.2	180	4.9	Mud/Sand
	-	-	-	-	-	
Adults	-	-	-	-	-	-
	-	-	-	-	-	

Table 15. Summary of the habitat associations for the Atlantic sharpnose shark, *Rhizoprionodon terraenovae*, by life stage in Mississippi/Alabama waters. Young-of-the-year includes neonate life stage. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the year	29.1 (26.6-31.4)	24.0 (18.9-29.2)	4.3 (3.0-5.3)	157.4 (122.0-220.0)	6.1 (4.7-7.0)	Slit/Clay/ Sand
Juvenile	28 (26.6 – 29.1)	26.4 (21.0-29.2)	4.3 (3.0-5.3)	167.3 (122.0-220.0)	6.2 (4.7-7.0)	Slit/Clay/ Sand
Adult	27.4 (25.5-29.1)	27.4 (21.0-30.2)	4.7 (3.0-5.8)	235 (121.0-244.0)	6.2 (4.7-7.0)	Sand/Silt/ Clay

Table 16. Summary of the habitat associations for the blacktip shark, *Carcharhinus limbatus*, by life stage in Mississippi/Alabama waters. Young-of-the-year includes neonate life stage. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the year	29.6 (29.1-30.1)	20 (18.9-21.0)	3.5 (3.0-4.0)	136 (122.0-150.0)	6.4 (5.9-6.8)	Sand/Silt Clay
Juvenile	29.0 (26.6-31.4)	25.5 (22.0-29.0)	5.0 (4.6-5.3)	178.0 (135.0-220.0)	6.4 (5.9-7.0)	Sand/Silt/ Clay
Adult	29.0 (26.6-31.4)	25.5 (22.0-29.0)	5.0 (4.6-5.3)	178.0 (135.0-220.0)	6.4 (5.9-7.0)	Sand/Silt/ Clay

Table 17. Summary of the habitat associations for the bull shark, *Carcharhinus leucas*, by life stage in Mississippi/Alabama waters. Young-of-the-year includes neonate life stage. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the-year	30.4 (29.6-31.2)	10.1 (7.0-13.2)	1.3 (1.3-1.4)	70.0 (68.0-80.0)	5.3 (5.1-5.5)	Mud
Juvenile	30.7 (29.6 – 31.4)	14.1 (7.0-22.0)	2.4 (1.3-4.6)	91.7 (68.0-135)	5.5 (5.1-5.9)	Mud/Sand/ Clay
Adult	- -	- -	- -	- -	- -	-

Table 18. Summary of the habitat associations for the finetooth shark, *Carcharhinus isodon*, by life stage in Mississippi/Alabama waters. Young-of-the-year includes neonate life stage. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the year	29.6 (29.1-30.1)	20 (18.9-21.0)	3.5 (3.0-4.0)	136 (122.0-150.0)	6.4 (5.9-6.8)	Sand/Silt/ Clay
Juvenile	29.1 -	21.0 -	3.0 -	122 -	6.8 -	Sand/Silt/ Clay
Adult	- -	- -	- -	- -	- -	

Table 19. Summary of the habitat associations for the bonnethead shark, *Sphyrna tiburo*, by life stage in Mississippi/Alabama waters. Young-of-the-year includes neonate life stage. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Young-of-the year	- -	- -	- -	- -	- -	-
Juvenile	27.5 (26.6-29.1)	25.0 (21.0-29.0)	4.2 (3.1-5.3)	171.0 (122.0-270.0)	6.0 (6.8-7.0)	Sand/Clay/ Mud
Adult	29.1 -	21.0 -	3.1 -	122.0 -	7.0 -	Sand/Mud

Table 20. Summary of the habitat associations for skates and rays in Mississippi/Alabama waters. Means are presented. Ranges are in parentheses. Bottom type is presented in descending predominance unless otherwise stated.

Life stage	Temperature (°C)	Salinity (ppt)	Depth (m)	Water clarity (cm)	Dissolved oxygen (mg l^{-1})	Bottom type
Atlantic stingray	31.4 -	22.0 -	4.6 -	135.0 -	5.9 -	Sand/Slit
Cownose ray	27.0 (26.8-28.7)	24.7 (23.1-26.7)	5.2 (4.6-5.8)	299.0 (160.0-438.0)	5.5 (4.7-6.3)	Sand/Slit/ Clay

Figure 1. Locations of sets made in 2005 for areas in St. Andrew Bay and Crooked Island Sound in the northeast Gulf of Mexico, Florida.

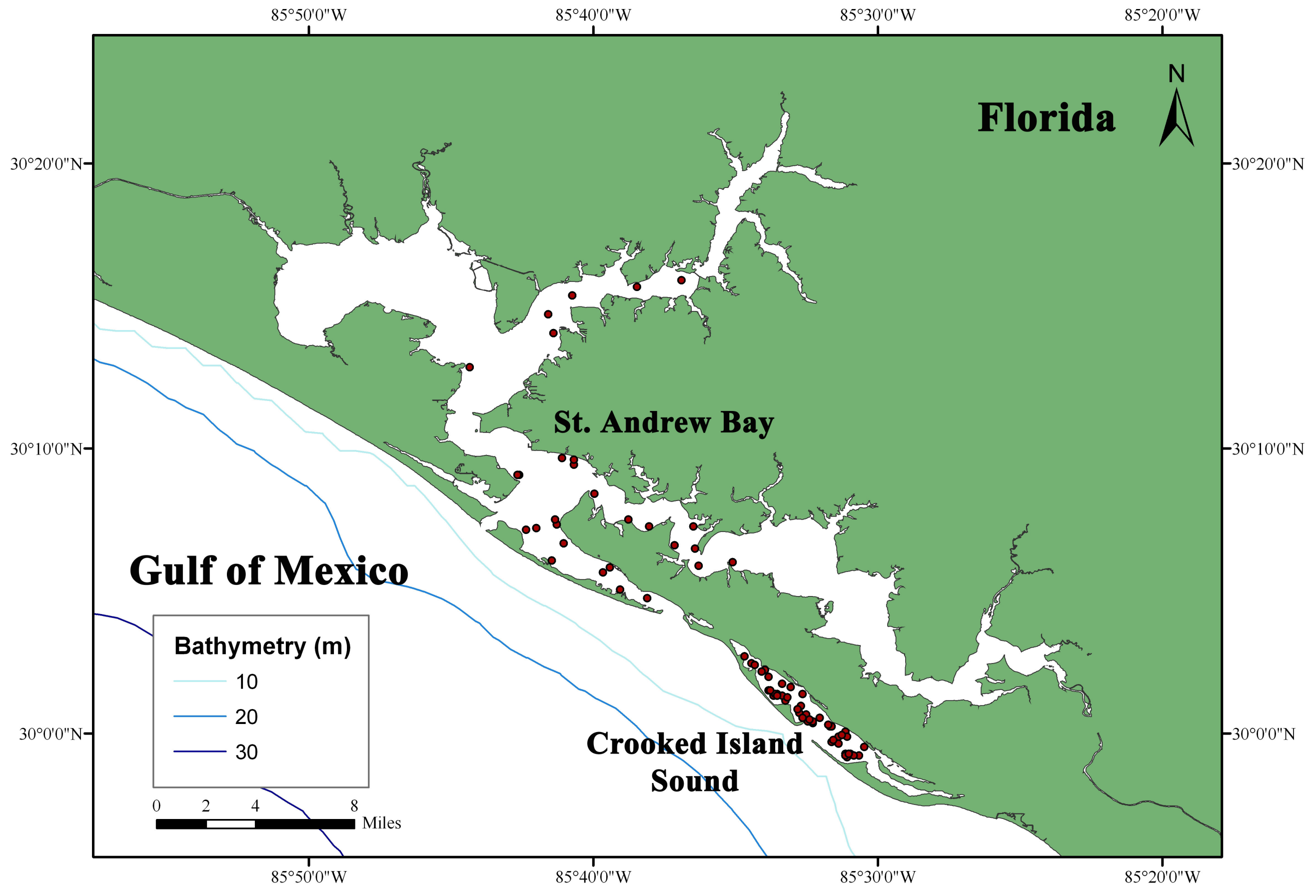

Figure 2. Locations of sets made in 2005 for areas in St. Joseph Bay and inside and outside of Apalachicola Bay, FL, in the northeast Gulf of Mexico, Florida.

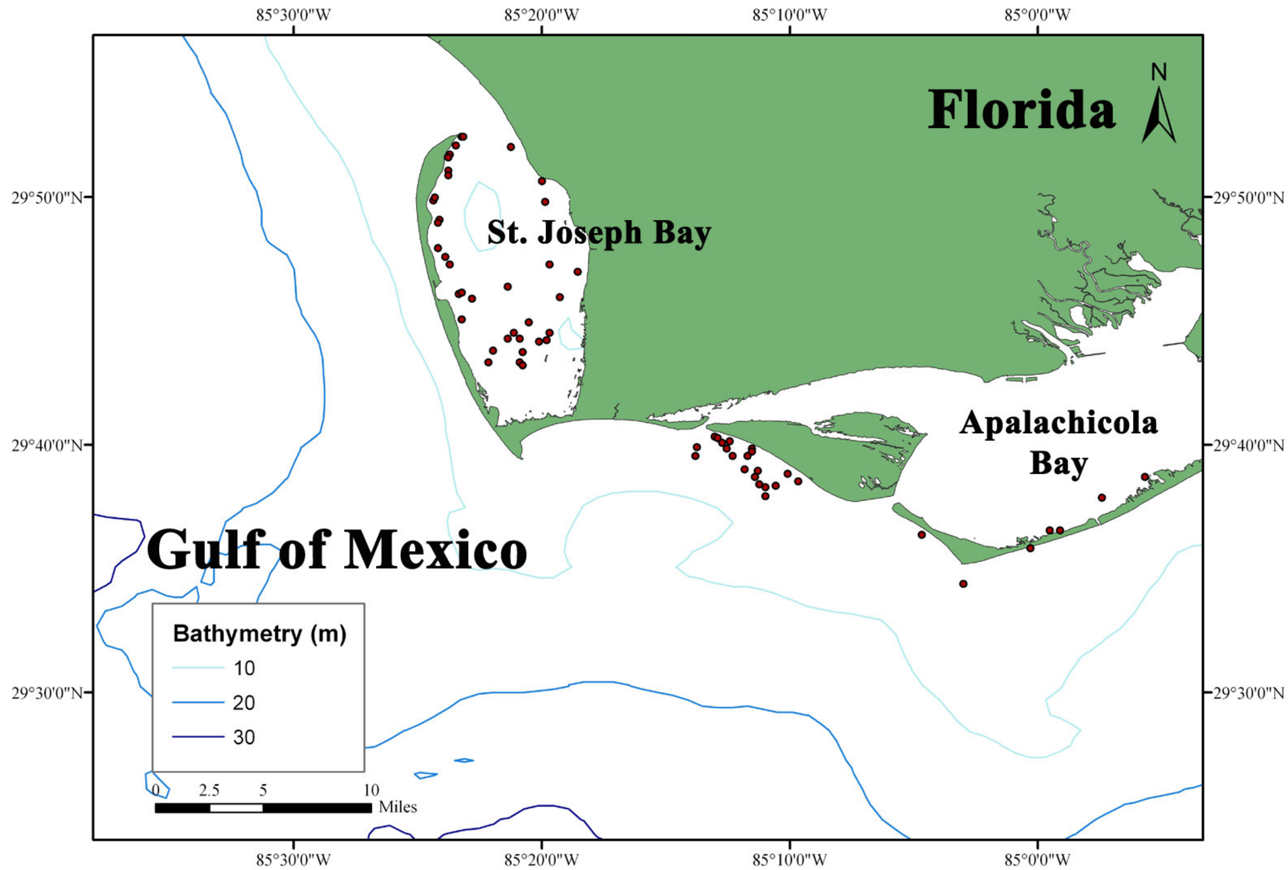

Figure 3. Deployment and pop-off locations of archival satellite tags attached to two bull sharks *Carcharhinus leucas* in the northeast Gulf of Mexico, Florida.

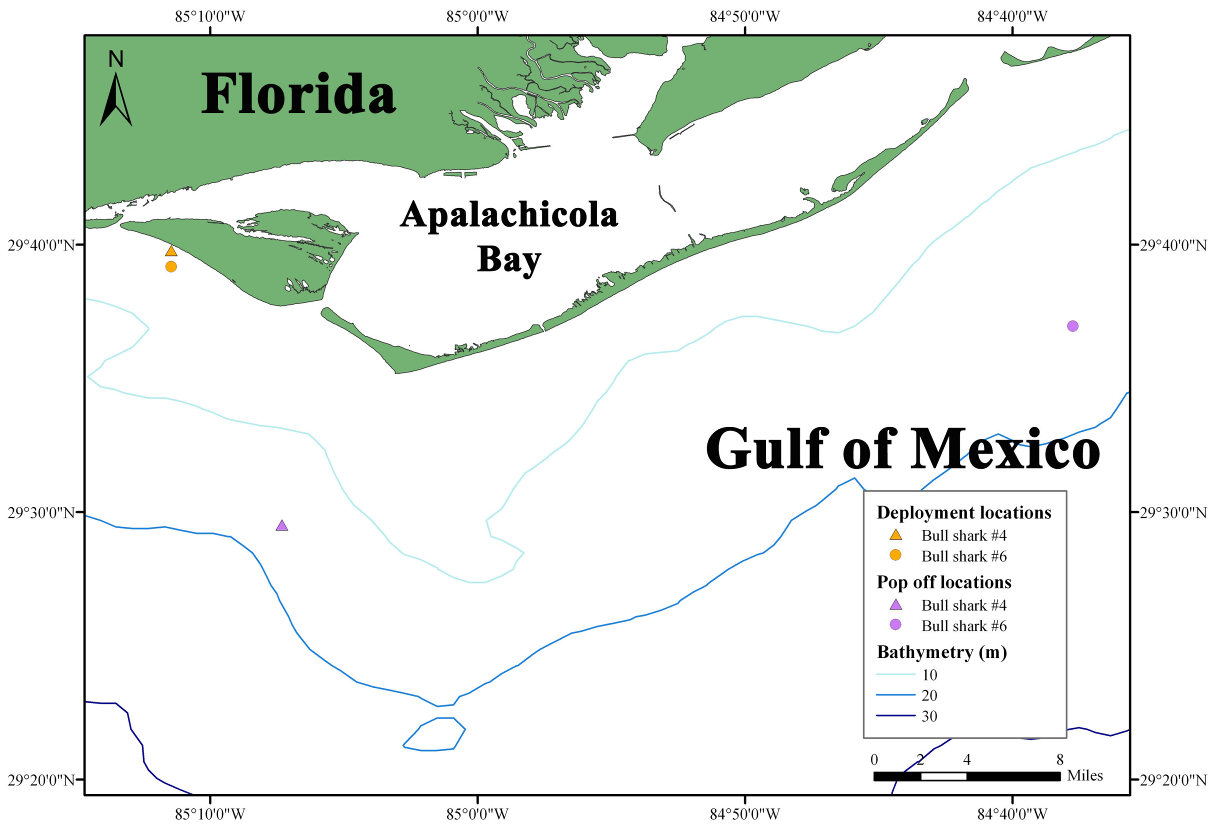

Figure 4. Locations of sets made in 2005 for areas in Mississippi/Alabama waters.